

SPECIFICATION

Electronic Version 1.2.8

Stylesheet Version 1.0

[Computed Tomography System with Integrated Scatter Detectors]

Background of Invention

[0001] The present invention relates generally to imaging systems and more particularly to computed tomography. A computed tomography or CT scan is a method of taking pictures of the inside of the body using an ultra-thin x-ray beam. As the x-ray beam passes through the body, it is absorbed by bones, tissues and fluid within the body, thereby varying resultant beam intensity. The intensity of the x-ray beam emerging from the body is measured by a device that converts x-ray beam data into a detailed picture.

[0002] Multi-slice CT scanners are special CT systems equipped with a multiple-row detector array rather than a single-row detector array. This allows for simultaneous scan of multiple slices at different locations.

[0003] A typical CT scanner includes a gantry having an annular frame for rotatably supporting an annular disk about a rotation or scanning axis of the scanner. The disk includes a central opening large enough to receive a patient extending along the scanning axis, and the disk is rotated about the patient during a scanning procedure. An x-ray tube is positioned on the disk diametrically across the central opening from an array of x-ray detectors. As the disk is rotated, the x-ray tube projects a beam of energy, or x-rays, along a scan plane, through the patient, and to the detector array. By rotating the x-ray source about the scanning axis and relative to the patient, x-rays are projected through the patient from many different directions. An image of the scanned portion of the patient is then constructed from data provided by the detector array using a scanner computer.

[0004] A disadvantage of the aforementioned system is that acquiring further information

requires either an increased dose of x-rays or an increased number of x-ray scans.

[0005] A further disadvantage of the aforementioned system is that back-scatter radiation is not utilized to obtain an increase amount of information about the patient. Back-scattering is the deflection of radiation or particles by scattering through angles greater than 90 ° with reference to the original direction of travel.

[0006] The disadvantages associated with current, CT systems have made it apparent that a new technique for CT scanning and data transfer is needed. The new technique should substantially increase information acquired from each patient and should also utilize back-scatter x-rays as a source of information. The present invention is directed to these ends.

Summary of Invention

[0007] In accordance with one aspect of the present invention, an imaging system includes a gantry and an x-ray source coupled to the gantry. The x-ray source is adapted to generate an x-ray flux, wherein a portion of the x-ray flux is adapted to become scatter radiation. A first scatter detector is also coupled to the gantry and is adapted to receive the scatter radiation. The scatter detector is further adapted to generate a first scatter signal in response to the scatter radiation. A host computer is adapted to receive the scatter signal.

[0008] In accordance with another aspect of the present invention, a method for data collection for an imaging system comprising: activating an x-ray source; generating an x-ray flux; receiving scatter radiation from said x-ray flux in at least one scatter detector; generating a scatter signal in response to said x-ray flux; and receiving said scatter signal in a host computer.

[0009] One advantage of the present invention is that it generates an increased amount of information from a scanned object without the need for increased dosage or an increased number of scans.

[0010] Additional advantages and features of the present invention will become apparent from the description that follows and may be realized by the instrumentalities and combinations particularly pointed out in the appended claims, taken in conjunction

with the accompanying drawings.

Brief Description of Drawings

[0011] For a more complete understanding of the invention, there will now be described some embodiments thereof, given by way of example, reference being made to the accompanying drawings, in which: FIGURE 1 is a diagram of a CT scanning system in accordance with a preferred embodiment of the present invention; FIGURE 2 is a block diagram of FIGURE 1; and FIGURE 3 is a block diagram of a method for scanning an object, in accordance with a preferred embodiment of the present invention.

Detailed Description

[0012] The present invention is illustrated with respect to a Computed Tomography (CT) scanning system 10, particularly suited to the medical field. The present invention is, however, applicable to various other uses that may require CT scanning, as will be understood by one skilled in the art. Referring to FIGURES 1 and 2, a CT scanning system 10 including a gantry 11, in accordance with a preferred embodiment of the present invention, is illustrated. An x-ray source 12, coupled to the gantry 11, generates an x-ray flux 17, which passes through an object 18 (e.g. a patient) and produces back-scatter radiation. The system 10 further includes a CT detector 13, coupled to the gantry 11, which generates a detector signal in response to the x-ray flux 17. A first scatter detector 19, generating a scatter signal in response to the scatter radiation, is also coupled to the gantry 11. Position and operation of the scatter detector 19 will be discussed later.

[0013] A CT control unit 15, including a host computer and display 24 and various other widely known CT control and display components, receives the detector and scatter signals and responds by generating an image signal. The CT control unit 15 also includes, for example, an operator console 23, an x-ray controller 25, a table control 29, a gantry motor control 30, a mass storage 39, an image reconstructor 41 and a data acquisition system 42, all of which will be discussed later.

[0014] The gantry 11 is the ring shaped platform that rotates around the scanned object 18 in response to signals from the gantry motor control 30, as will be understood by one skilled in the art. Ideally, the x-ray source 12, CT (multi-slice) detector 13 and

scatter detector 19 are coupled thereto.

[0015] The x-ray source 12 is embodied as a flat panel x-ray source or an extended x-ray source (e.g. Imatron), or a standard x-ray tube. The x-ray source 12 is activated by either a host computer 24 or an x-ray controller 25, as will be understood by one skilled in the art. The x-ray source 12 sends the x-ray flux 17 through an object 18 on a moveable table 27 controlled by a table control device 29 acting in response to signals from the host computer 24, as will be understood by one skilled in the art.

[0016] The x-ray flux 17 from the x-ray source 12 passes through the patient and impinges on the x-ray detector 13. The signal 17 passes directly to the host computer and display 24, where the signal is converted to a gray level corresponding to the attenuation of the x-ray photon through the patient, for the final CT image.

[0017] The CT detector 13 is typically located opposite the x-ray source 12 to receive x-ray flux 17 generated therefrom and includes several modules. Each module shares information with other modules corresponding to a number of slices.

[0018] Modern CT detectors typically have N slices in the table motion direction, where N is 4, 8, 16, or other number depending on system requirements. These multi-slice configurations extend area of coverage and offer reduced scan times and increased resolution.

[0019] The first scatter detector 19 is coupled to the gantry 11 however, numerous additional scatter detectors 20, 21, 22, 26, and 28, are coupled thereto to receive increased levels of back-scatter radiation. These scatter detectors can be from single cell to multiple cell detectors utilizing single slice or multiple slice configurations. They can also be a complete duplicate of detector 13 placed at these designated locations. Examples of locations on the gantry 11 for a first and a second scatter detector 19, 20 is on either side of the x-ray tube 12 (on a first side and a second side of the x-ray tube), the pair of scatter detectors 21, 22 on the other two sides of the X-ray tube 12 a portion of the circumference around the gantry 11 or alternately the pair of scatter detectors 26, 28 on both or on only one side of the CT detector 13.

[0020] The scatter detector 19 is ideally coupled relatively close to the x-ray source 12 and measures back-scattered x-ray flux as a function of the rotation angle of the

gantry 11. The detected scatter radiation versus view angle is utilized similarly to that of the transmitted x-ray flux to generate a CT image. The image is generated either during a standard CT scan or during a separate scan with alternate optimized x-ray radiation.

[0021] The present invention is illustrated with respect to CT, however it is alternately used for any type of x-ray system using detectors including mammography, vascular x-ray imaging, bone scanning, etc. Further embodiments include non-medical applications such as weld inspection, metal inspection. Essentially, anything that could use a digital x-ray detector to make 1, 2 or 3 dimensional images.

[0022] The host computer 24 receives the detector signal and the first scatter signal. The host computer 24 also activates the x-ray source 12, however, alternate embodiments include independent activation means for the x-ray source. The present invention includes an operator console 23 for control by technicians, as will be understood by one skilled in the art.

[0023] Data is acquired and processed, and a CT image, for example, is presented to a radiology technician through the monitor and user interface 37 while the scan is occurring. The host computer 24 needs only read the module and scatter signals and update the display at the appropriate locations through, for example, an image reconstructor 41 and data acquisition system (DAS) 42. The host computer 24 alternately stores image data in a mass storage unit 39 for future reference.

[0024] An alternate embodiment incorporates a similar host computer 24 in a flat panel x-ray source, such as the GE Senographe 2000D Full Field Digital Mammography System.

[0025] One embodiment of the present invention incorporates use of x-ray detectors for the scout scan on a CT system. During a scout scan from the x-ray source to the detector elements, the x-ray tube remains stationary while the patient table 27 translates under the x-ray flux 17. This results in a two-dimensional image ideal for qualitative information and for locating the desired position for scanning during further CT exams.

[0026] Referring to FIGURE 3, a block diagram of a Computed Tomography (CT) scanning

system 50 is illustrated. Logic starts in operation block 90 where the x-ray source is activated by the host computer. Subsequently, in operation block 92, the x-ray source generates an x-ray flux (signal), which typically travels through a patient.

[0027] Operation block 94 then activates, and the CT detector detects the x-ray flux and generates at least one detector signal, in operation block 96, in response to the x-ray flux.

[0028] Operation block 97 then activates, and the scatter detector detects the scatter radiation and generates at least one scatter signal, in operation block 98, in response to the scatter radiation resulting from the x-ray signal.

[0029] Operation block 99 then activates, and the host computer analyzes the detector signals, and updates the resultant scan image in operation block 100.

[0030] A check is then made in inquiry block 102 whether the scan is complete. For a positive response, the host computer stops scanning. Otherwise, operation block 92 reactivates and blocks 94, 96, 97, 98, 99, 100 and 102 subsequently activate in turn.

[0031] In operation, the method for data collection for an imaging system includes the steps of activating an x-ray source, thereby generating an x-ray flux. Following reception of the x-ray flux in at least one CT detector, a detector signal is generated and subsequently received in a host computer. Scatter radiation from the x-ray flux is received in at least one scatter detector, which generates a signal therefrom, which is received in the host computer.

[0032] The host computer cycles typical image processing steps in response to the detector and scatter signals, as will be understood by one skilled in the art. In other words, data offsets are corrected and x-ray dosage is measured and normalized. Necessary calibration corrections are made, and the resulting signal is filtered, typically through a low dose filter and an adaptive filter, to reduce noise in the signal. The signal is then converted to display pixel format and subsequently displayed.

[0033] From the foregoing, it can be seen that there has been brought to the art a new computed tomography scanning system 10. It is to be understood that the preceding description of the preferred embodiment is merely illustrative of some of the many

specific embodiments that represent applications of the principles of the present invention. Numerous and other arrangements would be evident to those skilled in the art without departing from the scope of the invention as defined by the following claims.

11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65
66
67
68
69
70
71
72
73
74
75
76
77
78
79
80
81
82
83
84
85
86
87
88
89
90
91
92
93
94
95
96
97
98
99
100
101
102
103
104
105
106
107
108
109
110
111
112
113
114
115
116
117
118
119
120
121
122
123
124
125
126
127
128
129
130
131
132
133
134
135
136
137
138
139
140
141
142
143
144
145
146
147
148
149
150
151
152
153
154
155
156
157
158
159
160
161
162
163
164
165
166
167
168
169
170
171
172
173
174
175
176
177
178
179
180
181
182
183
184
185
186
187
188
189
190
191
192
193
194
195
196
197
198
199
200
201
202
203
204
205
206
207
208
209
210
211
212
213
214
215
216
217
218
219
220
221
222
223
224
225
226
227
228
229
230
231
232
233
234
235
236
237
238
239
240
241
242
243
244
245
246
247
248
249
250
251
252
253
254
255
256
257
258
259
260
261
262
263
264
265
266
267
268
269
270
271
272
273
274
275
276
277
278
279
280
281
282
283
284
285
286
287
288
289
290
291
292
293
294
295
296
297
298
299
300
301
302
303
304
305
306
307
308
309
310
311
312
313
314
315
316
317
318
319
320
321
322
323
324
325
326
327
328
329
330
331
332
333
334
335
336
337
338
339
340
341
342
343
344
345
346
347
348
349
350
351
352
353
354
355
356
357
358
359
360
361
362
363
364
365
366
367
368
369
370
371
372
373
374
375
376
377
378
379
380
381
382
383
384
385
386
387
388
389
390
391
392
393
394
395
396
397
398
399
400
401
402
403
404
405
406
407
408
409
410
411
412
413
414
415
416
417
418
419
420
421
422
423
424
425
426
427
428
429
430
431
432
433
434
435
436
437
438
439
440
441
442
443
444
445
446
447
448
449
450
451
452
453
454
455
456
457
458
459
460
461
462
463
464
465
466
467
468
469
470
471
472
473
474
475
476
477
478
479
480
481
482
483
484
485
486
487
488
489
490
491
492
493
494
495
496
497
498
499
500
501
502
503
504
505
506
507
508
509
510
511
512
513
514
515
516
517
518
519
520
521
522
523
524
525
526
527
528
529
530
531
532
533
534
535
536
537
538
539
540
541
542
543
544
545
546
547
548
549
550
551
552
553
554
555
556
557
558
559
560
561
562
563
564
565
566
567
568
569
570
571
572
573
574
575
576
577
578
579
580
581
582
583
584
585
586
587
588
589
590
591
592
593
594
595
596
597
598
599
600
601
602
603
604
605
606
607
608
609
610
611
612
613
614
615
616
617
618
619
620
621
622
623
624
625
626
627
628
629
630
631
632
633
634
635
636
637
638
639
640
641
642
643
644
645
646
647
648
649
650
651
652
653
654
655
656
657
658
659
660
661
662
663
664
665
666
667
668
669
670
671
672
673
674
675
676
677
678
679
680
681
682
683
684
685
686
687
688
689
690
691
692
693
694
695
696
697
698
699
700
701
702
703
704
705
706
707
708
709
710
711
712
713
714
715
716
717
718
719
720
721
722
723
724
725
726
727
728
729
730
731
732
733
734
735
736
737
738
739
740
741
742
743
744
745
746
747
748
749
750
751
752
753
754
755
756
757
758
759
760
761
762
763
764
765
766
767
768
769
770
771
772
773
774
775
776
777
778
779
780
781
782
783
784
785
786
787
788
789
790
791
792
793
794
795
796
797
798
799
800
801
802
803
804
805
806
807
808
809
810
811
812
813
814
815
816
817
818
819
820
821
822
823
824
825
826
827
828
829
830
831
832
833
834
835
836
837
838
839
840
841
842
843
844
845
846
847
848
849
850
851
852
853
854
855
856
857
858
859
860
861
862
863
864
865
866
867
868
869
870
871
872
873
874
875
876
877
878
879
880
881
882
883
884
885
886
887
888
889
890
891
892
893
894
895
896
897
898
899
900
901
902
903
904
905
906
907
908
909
910
911
912
913
914
915
916
917
918
919
920
921
922
923
924
925
926
927
928
929
930
931
932
933
934
935
936
937
938
939
940
941
942
943
944
945
946
947
948
949
950
951
952
953
954
955
956
957
958
959
960
961
962
963
964
965
966
967
968
969
970
971
972
973
974
975
976
977
978
979
980
981
982
983
984
985
986
987
988
989
990
991
992
993
994
995
996
997
998
999
1000